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EXPERIMENTAL RADIO DATA SYSTEM (RDS):

A survey of reception reliability in the UK

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EXPERIMENTAL RADIO DATA SYSTEM (RDS): A SURVEY OF RECEPTION RELIABILITY IN THE UK

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Summary

The Report describes a field survey which was made to investigate the reliability of reception of the Radio Data System (RDS). Trade-test transmissions of RDS were introduced on all BBC Band II VHF/FM radio signals broadcast in England in August 1987. A full public service of RDS is expected to commence in England in mid-1988. The survey covered both mobile (car) and static (domestic) reception under various conditions. During the survey a microcomputer was used in the survey vehicle to analyse and log the data gathered about reception of the RDS data. Particular attention was given to investigating the reliability of reception of RDS under poor receiving conditions sometimes experienced in moving vehicles.

The survey related reliability of RDS reception to quality of received sound programme. The RDS reception analysis is given in term of 'waiting-time' for correct codes (noise performance in terms of bit-error-ratio statistics are not dealt with, having been studied elsewhere).

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EXPERIMENTAL RADIO DATA SYSTEM (RDS):
A SURVEY OF RECEPTION RELIABILITY IN THE UK

A.G. Lyner, B.Sc.

1. INTRODUCTION

RDS is a system for adding digital signals to broadcast VHF/FM sound signals[1]. The messages broadcast by this means are intended to be used by receivers primarily as an aid to tuning (either manually or automatically), and secondarily to provide supplementary information.

Various experimental versions of a radio-data system have been broadcast both in the UK and in some other countries over a period of several years during which time a specification for a suitable system has been developed within the EBU. This specification was agreed in 1982[2], and has been used for transmission in the UK since then, still on an experimental basis. An RDS service is planned to be introduced on all BBC National Network and Local Radio transmitters in the UK. Full scale trade-test transmissions commenced in England in August 1987, and operational service is expected in mid-1988.

Before arriving at the EBU specification, a considerable amount of work was undertaken by a number of European broadcasters on a variety of systems. This work established the degree of ruggedness and compatibility of each of the various systems. This was followed by comparative field trials of a number of selected systems in Switzerland in 1980[3]. These trials were made in order to arrive at a system, acceptable within Europe, with optimum parameters for satisfactory reception of data signals under most receiving conditions.

Before making the commitment of full implementation of a BBC RDS service it was decided that, in addition to the surveys which have been carried out elsewhere, a formal survey should be carried out in the UK. It was decided that this survey should provide information about the comparative performance of RDS in relation to the sound service rather than detailed 'absolute' information about coverage of the RDS service itself. This approach was thought to be realistic and considerably reduced the effort required. With the information provided by the survey, it should be possible to infer the probable reliability of reception anywhere in the UK assuming that the quality of reception of the sound service is known. It was expected that the survey would confirm that a useful RDS service could be obtained under any conditions under which a (reasonably tolerant) listener would be prepared to listen to the sound service. This would take into account a reduced expectation of sound quality whilst travelling by car.

2. RDS — THE RADIO DATA SYSTEM

The RDS signal is carried on a 57 kHz subcarrier which is added to the stereo multiplex signal at the transmitter, at the modulation input of the FM drive. The frequency deviation due to the injected subcarrier is recommended to be ±2 kHz. (The maximum deviation for the composite signal is ±75 kHz). This injection level was chosen after extensive compatibility and ruggedness tests to determine a level which would produce no impairment of the associated sound programme, and yet give adequately reliable reception of the RDS signals throughout the service area. (In practice, the deviation used by the BBC in experimental transmissions is ±2.25 kHz on all services except Radio 3 for which, in the interests of full compatibility with critical sound programme material, the deviation is restricted to ±1 kHz.)*

A summary of the RDS signal characteristics is given in Appendix 1 and full details are to be found in Ref. 2.

A short glossary of RDS terms and abbreviations is given in Table 1.

Table 1: RDS messages

Code Name	Application	Recommended minimum repetition rate per second†
PI	Programme identification	11
PS	Programme service name	1
PTY	Programme type code	11
TP	Traffic programme identification code	11
AF	Alternative frequency code	4
TA	Traffic announcement code	4
DI	Decoder identification code	1
M/S	Music/Speech code	4
PIN	Programme item number code	1
RT	Radiotext message	0.2
ON	Information concerning other networks	unspecified
IH	In-house applications	unspecified
CI	Clock time	one/minute

---

* The RDS service transmissions to be introduced in mid-1988 will use 2.0 kHz on all services except Radio 3 on which 1.2 kHz deviation will be used. These small changes from the injection levels tested in this work will have negligible impact upon ruggedness or compatibility.

† These are minimum recommended repetition rates and may often be exceeded.

2.1 Basic kinds of RDS message

A wide range of data messages may be transmitted by RDS. The main types of message and their code abbreviations are shown in Table 1. There are two basic kinds of message.

First, there are those messages which are short and repeated frequently, such as the PI, PTY and TP codes. The repetition rate for these codes is at least 11 times per second, which is the maximum which the system will conveniently allow. A receiver must display or respond to these messages as fast as possible, for instance when it has been tuned to another frequency and the user (or the processor within the receiver) needs to be certain that the correct programme or programme type has been found.

The second class of message is transmitted less frequently. It includes PS codes consisting of up to eight alphanumeric characters which announce the name of the programme service (e.g. BBC R4) once per second. Text of any length may be transmitted using sequences of RT codes and might well be sent only once. This kind of message is comparatively susceptible to corruption but its integrity is not so important.

2.2 Possible applications for RDS

The messages which are received and acted upon will depend upon the kind of receiver and the conditions under which it is being used. It is not fully known, at the time of writing, how receiver manufacturers plan to use the wide variety of RDS messages. The specification allows for great flexibility in many of the features of the system. Listed below are some of the different situations in which RDS might be used.

2.2.1 Fixed (domestic) reception

A receiver used under these circumstances would be expected to be provided with a relatively good signal. In a well served area this could be provided by a suitably orientated whip antenna on the receiver but, in many areas, would require a separate elevated antenna.

An expensive fixed receiver would quite possibly have a relatively high degree of intelligence and be capable of using most of the RDS messages. In addition to having the capability of using the 'machine level' codes to facilitate fast and reliable tuning it could have a sufficiently large visual display on which the RT messages might appear. Those messages, which are the most vulnerable to interference, are best suited to the use of receivers which can be provided with good antenna systems.

2.2.2 Portable and mobile reception (simple receiver)

A simple RDS receiver would have a limited text display and data entry facilities. The cheapest type of RDS receiver might have a display of only a few characters; enough, for example, to show the PS codes. Even with no further RDS facility such a receiver would be very convenient to tune compared with a conventional receiver

2.2.3 Mobile reception (intelligent receiver)

Although modern car radios have become very sophisticated, with the addition of automatic search tuning and memory to store manually entered alternative frequency lists, no present-day receiver completely solves the problem of automatically providing continuous reception of a wanted programme as the vehicle moves from the service area of one transmitter to that of another. Future RDS receivers will be able to achieve this objective without the need for tedious manual preprogramming of alternative frequency lists. To achieve best results the RDS receiver must use (and the broadcaster must broadcast) the following information:

(i) Alternative Frequency (AF) list to indicate what frequencies to switch to.

(ii) Programme Identification (PI) code to confirm that the broadcast on an alternative frequency is the wanted programme (by comparison with the PI code of the presently selected programme).

(iii) Other Network (ON) information to keep the receiver informed about AF lists and PI codes for programmes other than that presently selected. These are needed to allow quick access to these other programmes.

Speed of acquisition of the PI code is important in order to achieve acceptably short response times when search tuning (unless the rather expensive option of a dual front-end receiver is used).

Whilst it would be unsafe to display RT messages to the driver of a car it would be quite feasible to use a voice synthesiser. Under marginal reception conditions data errors would occur but the redundancy in the language would aid the listener in making sense of the message. The results of the survey (Section 7) imply that for long periods of mobile reception tolerable reception of RT codes could be expected.

2.2.4 Mobile reception of traffic information

The TP and TA codes are intended primarily for reception in cars. TA codes, are transmitted four times each second. The length of time in advance of the announcement that the TA codes will need to be sent will depend upon the minimum time in which a car might be expected to receive a code successfully. This survey did not include a detailed examination of this particular type of service. However, it is possible to infer that the reception reliability for the TP and TA codes would be somewhat better than for the PS codes.

3. AIMS OF THE SURVEY

As mentioned in the Introduction, it was decided that the criterion by which RDS should be judged should be the reliability of reception of RDS messages under conditions of acceptable reception of the associated sound programme. (This differs from the detailed analysis of the bit-error performance which was carried out in earlier field trials[3], the results of which were used to arrive at the present specification).

For the survey it was necessary to bear in mind that the primary purpose of RDS is to facilitate rapid and reliable station or programme selection[1]. In general this is achieved using short messages transmitted with the higher repetition rates. The other facilities available on RDS involve either long or infrequently transmitted be of secondary importance.

4. EQUIPMENT USED FOR THE SURVEY

4.1 The vehicle

It was decided that it would be best to conduct both mobile and fixed-site measurements using a Research Department survey vehicle, with a 10 m pneumatic mast. This meant that static measurements, simulating domestic reception, could be made at any time using the mast, in between the longer-running mobile measurements. A further advantage of using a van was that modifications to the layout of the equipment during the early stages of the survey were much more convenient than if the equipment had been fitted into a saloon car for the mobile survey. Section 5.1 describes steps which were taken to ensure that the results gathered in the survey vehicle would be valid for normal car reception.

4.2 Vehicle equipment

Fig. 1 is a photograph of the interior of the survey vehicle and Fig. 2 is a schematic diagram of

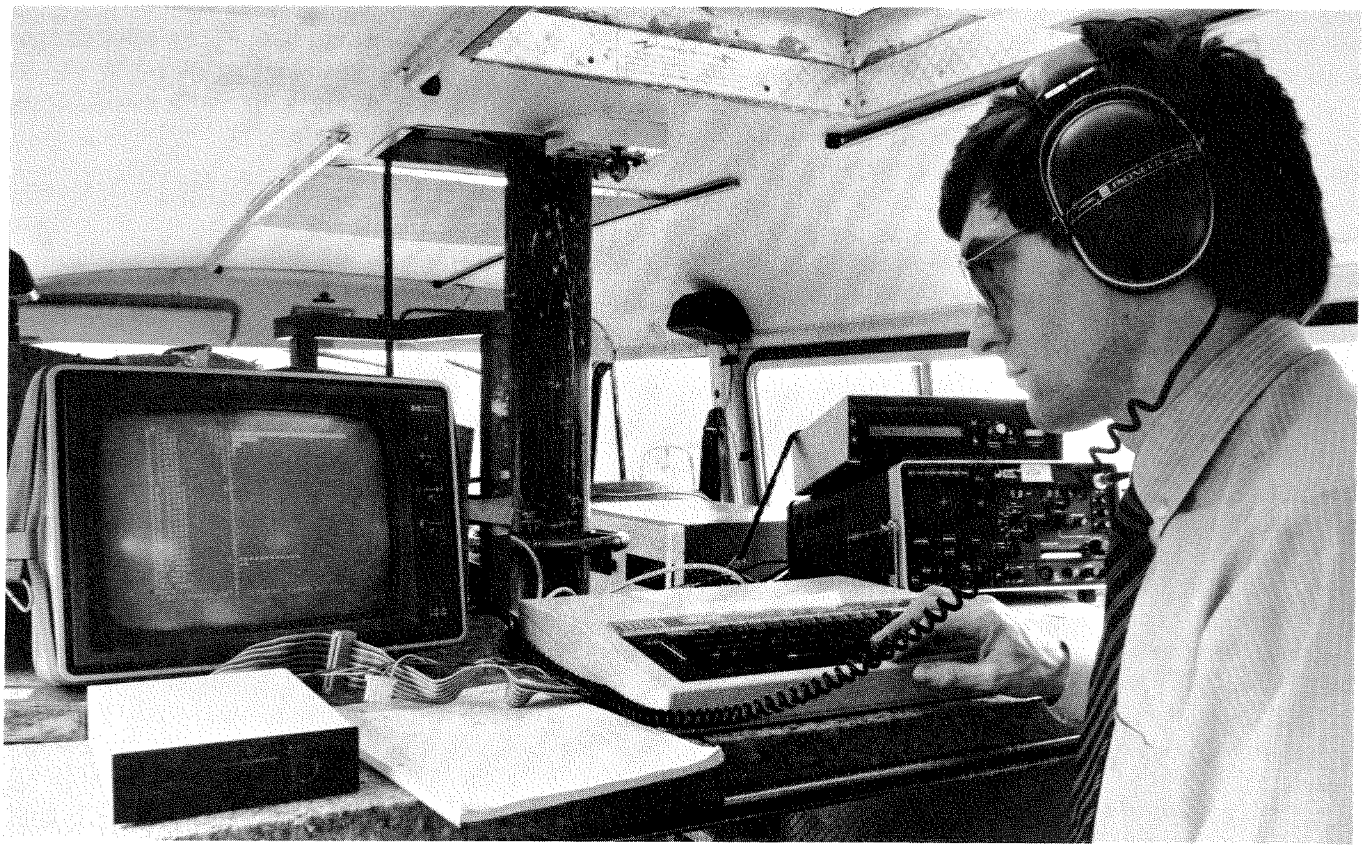

Fig. 1 - The interior of the survey vehicle.

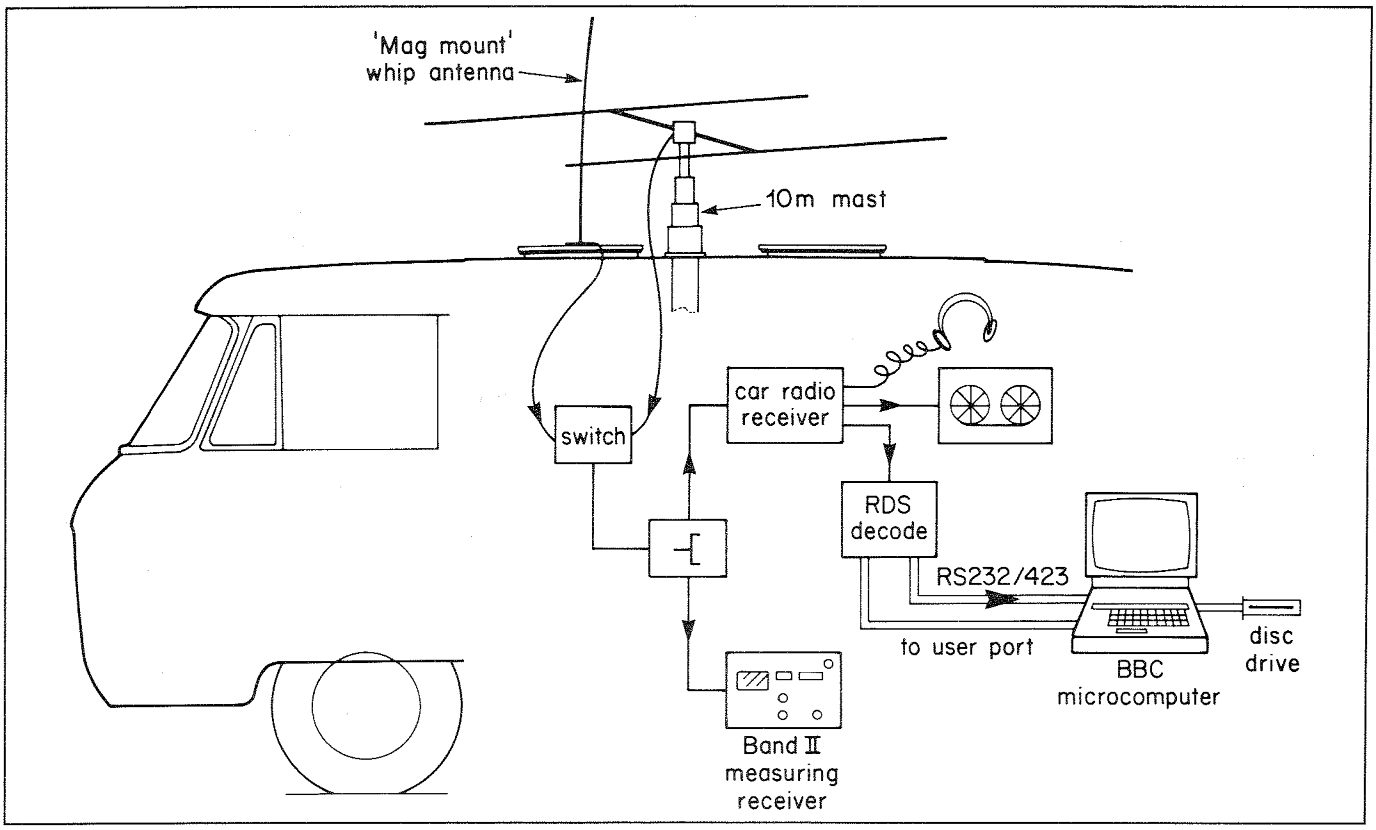

Fig. 2 - The equipment used for the survey.

the equipment used in the vehicle. Two antennas were used, a vertical 'mag-mount' whip fitted to the roof of the vehicle and a two-element Yagi fixed to the top of a 10 m pneumatic rotatable mast.

The signal from each antenna was split to provide feeds for a stereo car radio receiver and a multipath/field-strength measuring receiver. The audio output signal from the car radio receiver was fed to a pair of headphones and also to a tape recorder; recordings were made for listening assessments back at base.

The car radio receiver was modified to provide an output of the stereo multiplex signal. This signal was fed to an RDS decoder. The decoder had an alphanumeric display which could show selected types of received RDS messages. An RS232 interface passed these selected messages, as they were received, to a BBC microcomputer (via the RS423 serial port) which was used for the analysis of the survey results. In addition, the recovered RDS clock signal was fed from the decoder to the microcomputer.

4.2.1 The car radio receiver

A good-quality domestic car radio receiver was used. It uses a ratio detector for its frequency discriminator and was selected for its good performance.

4.2.2 The microcomputer

A BBC Model B microcomputer was chosen for the analysis and data logging because of its versatility and because of familiarity with its operating system and peripheral hardware.

4.2.3 The Band II measuring receiver

A commercial measuring receiver which provided a digital display of received field strength was employed. In addition, it provided a small CRT display which indicated the presence of any multipath distortion.

The operation of the multipath indicator is best described with reference to the CRT display (shown in Fig. 3). The x-axis is fed from the FM discriminator output and shows the instantaneous frequency of the received carrier. The y-axis shows the received signal amplitude. The presence of multipath interference is indicated by amplitude variations (shown on the y-axis) occurring as the programme modulates the x-axis. The maximum slope on the trace gives an indication of the level of distortion to the programme which will be caused by multipath interference. Measurements are made by altering the vertical gain of the CRT scan to bring the maximum slope of the trace parallel with a pair of cross-wires. The gain control is calibrated in '% per kHz' which dimensionally describes the product of the level of interfering signal and its relative delay. It has been found that this product is a very good indicator of likely level of audible impairment due to multipath distortion.

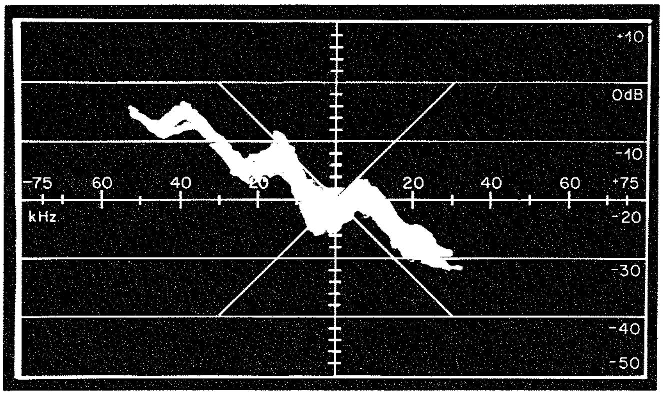

Fig. 3 - The multipath indicator display.

This method of measuring multipath interference has the great advantage of not requiring the transmission of special signals.

The form of display was intended for static measurements; when used in a moving vehicle the undulations on the CRT trace were seen constantly to be changing position. Nevertheless, their amplitudes did not change significantly over short periods and it was found to be quite possible to assess levels of multipath interference with the survey vehicle in motion and to produce figures which agreed sufficiently well with static measurements for the purpose of the survey.

4.2.4 The RDS decoder

The RDS decoder was a type which had been designed and built by Research Department and which was easily modified to provide the appropriate signals for passing to the microcomputer. The decoder implemented error correction for error bursts of two bits or less in a block. This error-correction strategy is now not thought to be optimum for control codes and PI codes because about 2% of all error patterns remain unrecognised. A better approach would be to select error correction or error detection adaptively according to the message content of the block being decoded.

5. THE SURVEY

As stated in Section 3, the purpose of the survey was to find out how useful RDS would be, in practice, to the car radio listener. Consequently the procedure used in the survey attempted to relate the reliability of RDS with the subjective quality of the received programme. It was decided that the performance of RDS under extremely bad sound reception conditions was of minor interest.

The scope of the survey was limited to the reception of PI and PS codes. Taken together the PI codes, being short and rapidly repeated, and the PS codes, being longer and with a lower repetition rate, are representative of all types of RDS message. The relationship between PS and PI message reception and that of the other types of message is discussed in Section 8.

5.1 Preliminary work

One important aim of the survey was to show the performance of RDS under typical mobile reception conditions. It was necessary, therefore, to check that reception in the survey vehicle was not significantly different from mobile reception in a saloon car. This involved checking that the directional sensitivity of the roof-mounted antenna was similar to that of typical saloon cars and conducting comparative listening tests in both types of vehicle. The higher level of ambient noise in the survey vehicle was another factor to be considered.

5.1.1 Radiation pattern measurements of the vehicle antenna

It was important to ensure that there was no significant asymmetry in the radiation pattern (sensitivity pattern) of the roof-mounted aerial. The vehicle was mounted on a turntable on an aerial measuring range and its horizontal radiation pattern (HRP) was measured. Both E-plane and H-plane patterns were measured. The HRP for mixed-polarization cannot be known because the relative phases of the two polarisation components of the received signal are unspecified, but a worst-case pattern (i.e. the least omnidirectional pattern) may be deduced by adding the cross-polar sensitivities in the direction of the V_p maxima and subtracting the cross-polar sensitivities in the direction of the V_p minima. Fig. 4 shows the two radiation patterns. Fig. 5 shows, for comparison, the HRPs of some typical car aerials mounted on saloon cars. It was concluded that using a roof-mounted aerial on the van introduced no significant errors into the survey measurements.

5.1.2 Comparative listening tests

The survey vehicle and a typical saloon car were each fitted with identical VHF stereo car receivers. The survey vehicle receiver was fed from its mag-mount whip aerial on the roof and the saloon car receiver was fed from a conventional car aerial.

The two vehicles were driven in convoy on a route where the received signal level is high and the

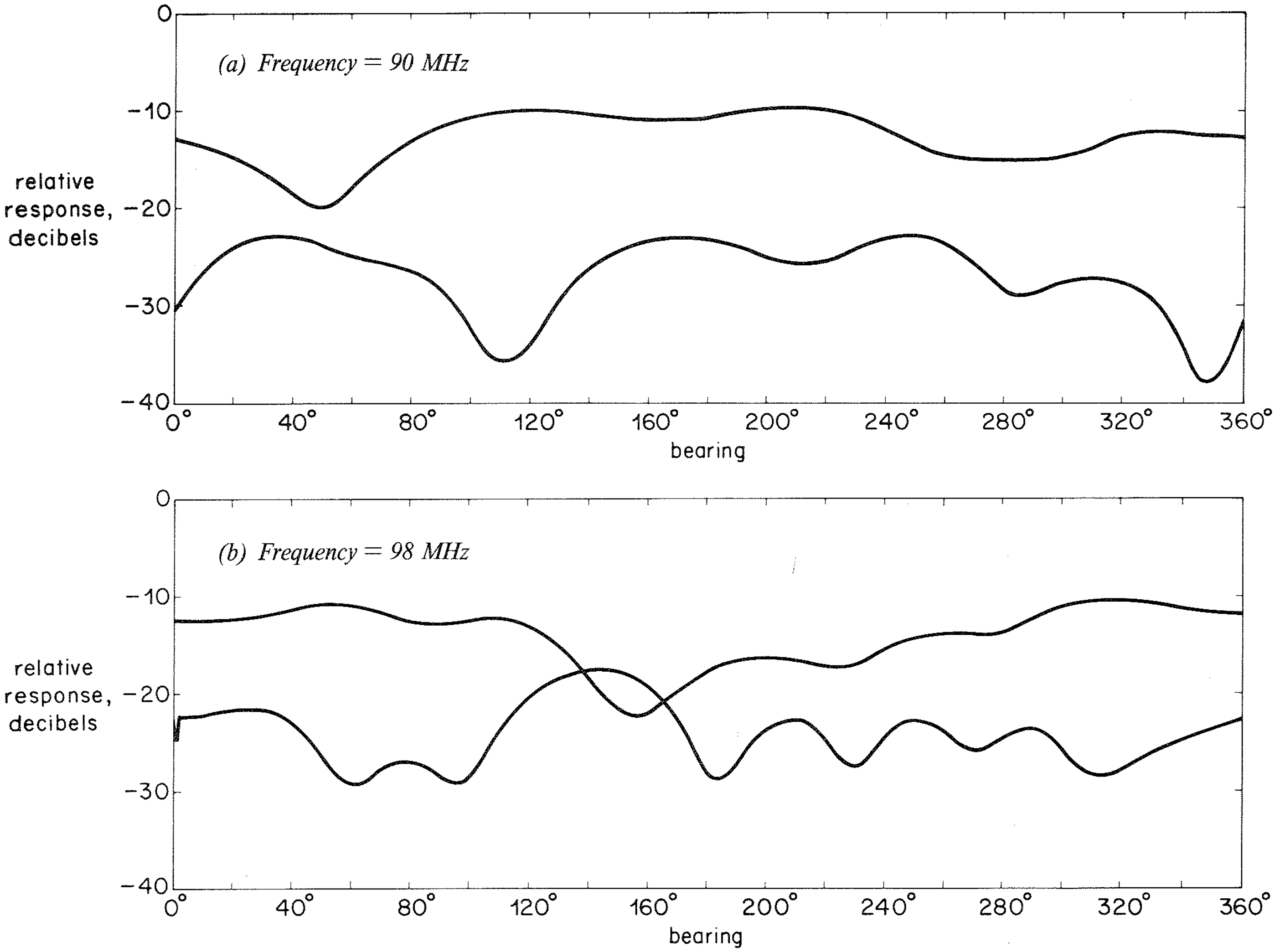

Fig. 4 - The radiation pattern of the roof-mounted 'mag-mount' whip antenna.

multipath interference is known to be particularly bad. The outputs of the two receivers were recorded on two high-quality cassette tape recorders and these recordings were replayed and compared under quiet listening conditions.

During this listening test, although the periods of worst distortion occurred at different times for the two recordings, there was no significant difference between characteristics of the impairment. It was concluded therefore that the results of a survey using a van could justifiably be applied to normal car reception.

When the vehicle engine was running the noise level inside was much higher than might be expected in a modern saloon car. This problem was dealt with by providing the operator with 'closed' headphones. These reduced the level of mechanical noise sufficiently to allow the operator to detect fairly low levels of impairment. The level of detectable impairment was found to correspond to CCIR quality Grade* 4 (Good). This was considered to correspond to the best listening conditions likely to be encountered in a moving car. Because of this, the best grade awarded to the sound programme received on the move was Grade 4. In practice the number of times RDS messages were lost when the sound quality was Grade 4 (Good) or 5 (Excellent) was insignificant.

5.2 The Survey measurement procedure and real-time error analysis

The assessment of RDS reception performance was carried out using a microcomputer which logged and analysed the reception of selected RDS messages (PI or PS codes). It was decided that the most relevant factor in judging the reliability of RDS reception was the time taken to receive successfully a chosen type of message. This contrasts with the approach adopted by previous workers[3,4] who have measured the proportion of messages correctly received. A more detailed descripton of the software may be found in Appendix 2 but the basic principle is as follows:

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* CCIR Recommendation 562-1

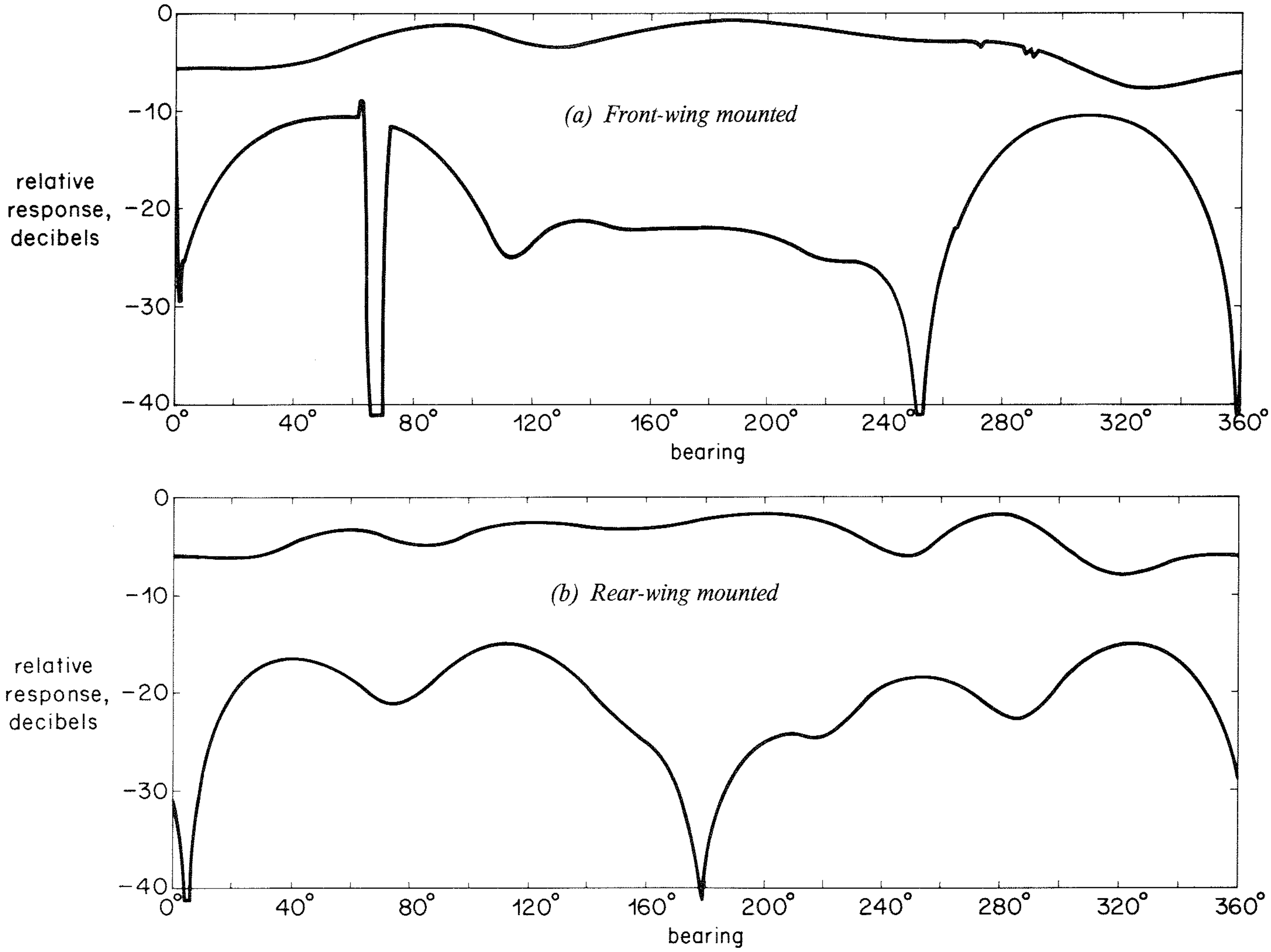


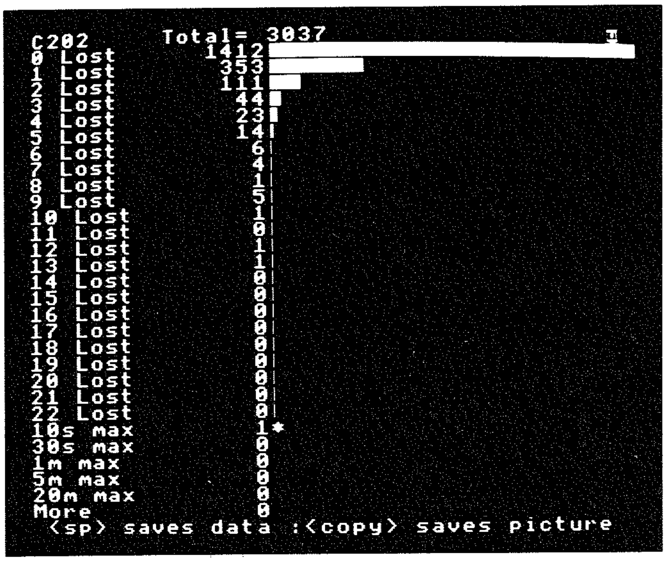
Fig. 5 - Radiation patterns of two typical car radio antennas.

The car receiver was manually tuned to the station of interest. A switch on the RDS decoder selected whether PI or PS codes were to be fed to the computer. The computer program was initialised at the beginning of a measurement period to look for a particular message. (For example C202 was the PI code associated with BBC Radio 2 in the experimental broadcasts).

The program first verified that the code had been correctly received using bit-by-bit comparison with the stored code. In some cases this strategy could slightly overestimate the effective number of failed PS messages which would often be quite readable with a single incorrect character and yet the program would log a failure.

Having received a correct code the computer counted the number of codes missed before next receiving a correct message. (The repetition rate of the codes was known and fixed in the case of the experimental transmissions used in the survey.) A frequency distribution was then built up, accumulating the number of occasions on which there were losses of 0, 1 or 2 messages etc. These statistics were accumulated and displayed on a monitor in the form of a histogram. An example of the display is shown in Fig. 6. Under good reception conditions the histogram would consist of a single column, showing that no messages had been lost. As reception conditions deteriorated the other columns would grow. Under some conditions, there could be a long wait between successful reception of a wanted code. To remove the need for an indeterminate length of ‘waiting-time axis’ on the histogram a ‘bin’ was created into which these long waiting times were collected. This showed the number of times the signal was lost for various coarsely-quantised times (see Fig. 6). In practice, it was found that entries were nearly always made in the ‘bin’ only during times when there was bad impairment to the sound programme.

At the end of a measurement period the analysis was stopped and the data contained in the histogram was stored on floppy disc, along with comments about the subjective quality of the received sound programme and other factors, such as the levels of received signal and multipath interference.



```
C202        Total= 3037
0 Lost         1412
1 Lost          353
2 Lost          111
3 Lost           44
4 Lost           23
5 Lost           14
6 Lost            6
7 Lost            4
8 Lost            1
9 Lost            5
10 Lost           1
11 Lost           0
12 Lost           1
13 Lost           1
14 Lost           0
15 Lost           0
16 Lost           0
17 Lost           0
18 Lost           0
19 Lost           0
20 Lost           0
21 Lost           0
22 Lost           0
10s max           1*
30s max           0
1m max            0
5m max            0
20m max           0
More              0
 <sp> saves data :<copy> saves picture
```

Fig. 6 - The computer display.

5.3 The choice of receiving sites and routes for the survey

The survey was carried out in an area to the south and west of the Wrotham transmitter where there is a wide variety of receiving conditions. Severe multipath interference was known to be present in parts of south London and on the edge of the North Downs where, in both cases, the field strength is high. There are also areas where the field strength is low and where there is a combination of multipath interference and low field strength.

It was soon found that data reception is very good at fixed sites with good programme reception quality, so the majority of survey time was spent in areas where the received sound was known or expected to suffer from some degree of impairment. Fig. 7 is a map of the survey area showing the service area of Wrotham transmitter and the routes covered during the mobile survey. It also shows the static survey points.

The service area of Wrotham transmitter is largely bounded by terrain features such as the North and South Downs and the static survey points were chosen mostly to be at the edge of the service area.

Routes which were known to have stretches with reception problems were selected for the survey. Some routes were traversed several times. On some occasions this was done with the receiver tuned to a different station each time. On other occasions the receiver was tuned to the same station twice in order to study the variation in reception quality from day to day.

5.4 Procedure during the mobile reception survey

The subjective quality grade of the received programme was noted, along with relevant information about field strength and multipath interference levels. The computer analysis program was then started, and the received data was analysed as described in Section 5.2, building up the histogram showing the frequency distribution of delay times. The analysis was left running for as long as the subjective grade of the received programme and the other factors remained the same.

When one or more of the factors changed or was expected to change, say on entering a motorway interchange or going over the edge of an escarpment, that particular analysis period was terminated and the totals were recorded on a file along with comments about subjective grade and signal strength or multipath levels. Thus, at the end of say two hours' surveying, there would be a large number of frequency distribution records on file. Each of these records would correspond to various analysis periods with times ranging from a few seconds to many minutes.

Later, during the data processing, the records of all analysis periods sharing a particular attribute were selected and the frequency distributions merged together. (See Section 6).

In Section 5.2 mention was made of the 'bin' which was used to record occasions when the wanted code was lost for long periods of time. However, a dilemma arose from time to time as to how to treat some of the entries placed into this 'bin'.

There were some occasions during the mobile survey when the subjective grade of the sound programme was judged to be 'Good' (Grade 4) or 'Fair' (Grade 3) over a period of many minutes. During these periods there would, very occasionally, be entries in the 'bin', usually corresponding to waiting times of a few seconds. (These were sometimes observed to correspond with short periods of impairment of sound quality which were not judged by the listener to influence the subjective grade significantly). The other entries in the 'bin' may have occurred during passages of non-critical programme material. There seems to be no other way of accounting for them and their presence in the tables of results should be noted taking this into account.

BBC

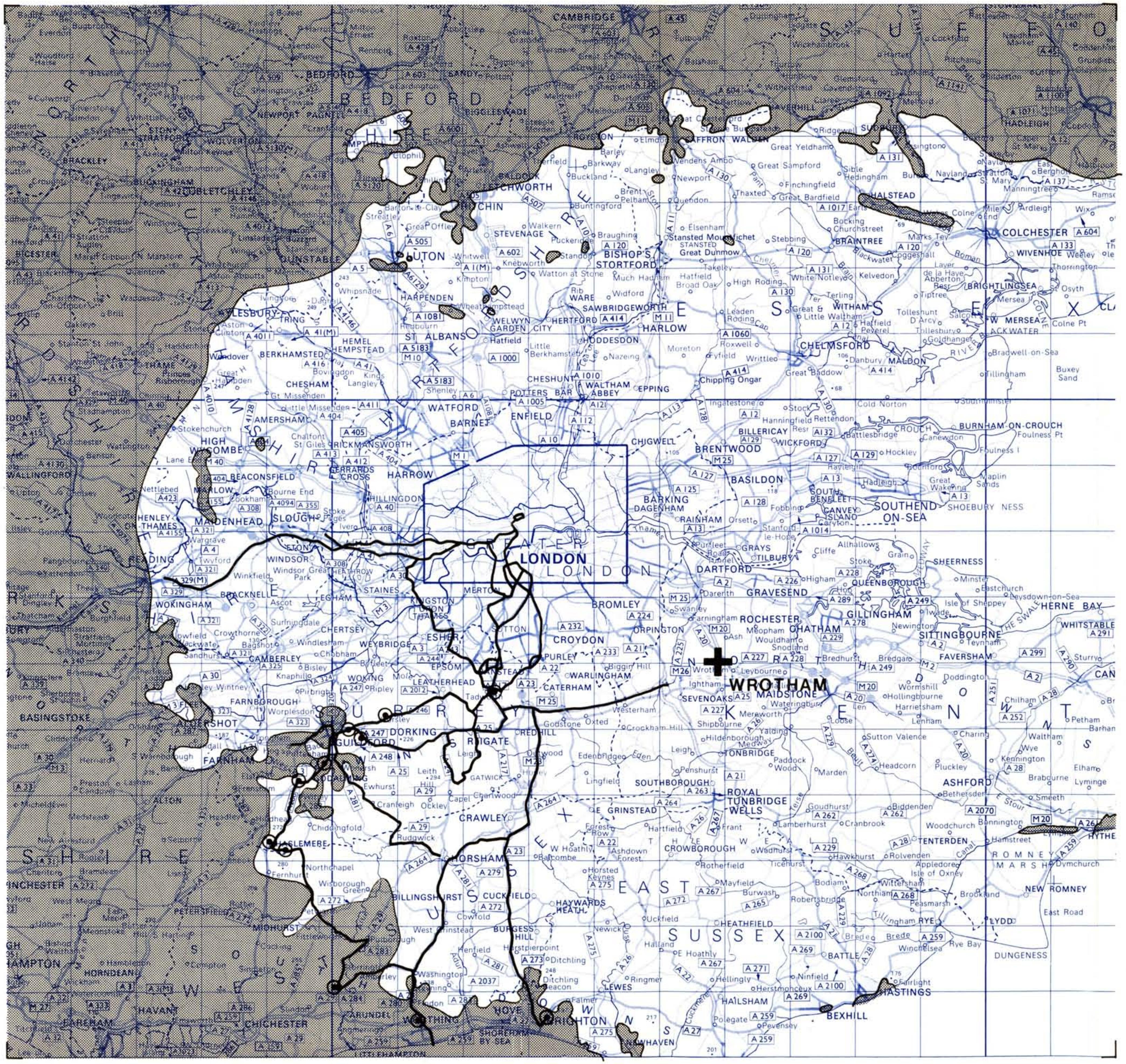


FIG 7
RECEIVING SITES AND ROUTES USED DURING THE SURVEY

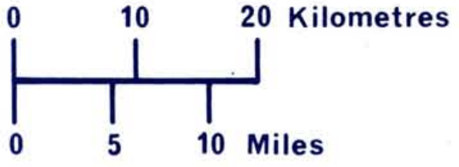
Map key

— Routes used for mobile survey

⊙ Points used for static survey

▨ Areas with field strength $<54\text{dB}(\mu\text{V/m})$@ 10m a.g.l.

— Service area boundary (fixed installations)



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5.5 The procedure at fixed sites

A similar procedure was used to that of the mobile survey but, as the quality of sound reception did not vary over the relatively short time used for each measurement, a period of a minute or so was used for each analysis.

It was found that, whilst it was possible to orientate the receiving aerial at some fixed locations to obtain bad RDS reception on one channel, this was always accompanied by a lower sound quality than would be considered acceptable at a static site.

6. ANALYSIS OF THE RECORDED DATA

After several days, records had been accumulated of a large number of analysis periods, each record consisting of a subjective quality grade for the received sound programme, values of field strength and multipath interference levels and a frequency distribution. Final analysis of the data consisted of gathering together all the frequency distributions sharing a particular set of attributes and accumulating the results and producing grand totals for each frequency distribution.

During the static survey the reception of RDS codes was 100% successful within the nominal service area, once the (elevated) receiving aerial was orientated for optimum sound quality. It was decided, therefore that further analysis of the static survey measurements would not yield useful information.

The mobile survey results were gathered into selected sets to bring out the effects of the various reception parameters. The results were grouped to bring out the following:

> Differences between PI and PS code reception.
>
> Differences between reception of RDS on Radio 2 (normal subcarrier injection level) and Radio 3 (low injection level).
>
> Overall reception statistics.
>
> Reception statistics where field strength is high and where multipath interference is the only likely impairment.

There were very few instances where there was a combination of low signal strength and low multipath interference. This was found to be the case even on routes which were distant from the transmitter and on flat terrain, such as on the M4 Motorway west of Slough. It was concluded that this particular combination of reception conditions would be rare. Consequently there seemed little point in trying to show the performance of RDS under these conditions.

7. RESULTS

7.1 Static site survey

For fixed receiving sites, with an antenna 10 m above ground level, there was 100% reception of PI and PS codes at every site chosen on the boundaries and within the published service area of Wrotham Transmitter. The reception quality of the sound programme was assessed as Grade 4 (Good) or Grade 5 (Excellent) at all static receiving sites.

On some occasions signals were received at sites well outside the nominal service area. On other occasions multipath interference was deliberately introduced at sites within the service area by orientation of the aerial. Under such conditions RDS messages were sometimes lost, but only when the received programme quality was regarded as unsuitable for listening at a fixed site.

By pointing the receiving antenna at a distant transmitter which also carried the RDS signal it was possible to obtain a wide range of reception quality. Various combinations of field strength and multipath interference levels were noted on the received signal. Under steady conditions (i.e. in the absence of aircraft flutter or the effects of nearby swaying trees) it was found that the RDS signal was either received with nearly 100% success or else hardly at all. The point at which the RDS signal failed corresponded to a received sound quality of about Grade 2 (Poor). There was a slight difference in favour of the RDS signal with the higher subcarrier injection level but this was judged to be irrelevant bearing in mind the poor quality of the received sound programme.

7.2 Mobile survey

Tables 2 to 9 show the results of the mobile survey. Each table shows the frequency distribution of the delay (expressed as the number of codes which were lost before successful reception of a code) for various subjective grades of received programme quality. These tables correspond to the computer display (see Fig. 6) used during the survey.

The eight tables may be divided into two groups of four, in three different ways. This makes it possible either to contrast PI code reception with PS code reception, or to show the effect of reduced injection level on Radio 3, or to indicate how the performance is affected by mean received signal strength.

Tables 2, 3, 4 and 5 show PI code survey results whilst Tables 6, 7, 8 and 9 show PS code survey results. In comparing the results of these two groups of tables one must bear in mind that there is an eleven-fold difference in time-scale between them; this is because the delay is expressed in terms of numbers of lost codes. (It should be remembered that PI codes are transmitted eleven times more frequently than PS codes[1]).

Tables 2, 3, 6 and 7 show the survey results for the RDS codes transmitted with Radio 2 (2.25 kHz injection level) and Tables 4, 5, 8 and 9 show the survey results for RDS codes transmitted with Radio 3 (1 kHz injection level).

Tables 2, 4 6 and 8 show the results gathered under all reception conditions and Tables 3, 5, 7 and 9 show the results corresponding to received signal levels of 36 dBμV or higher. The results were divided in this way to contrast the performance of RDS under mobile conditions within the nominal reception area with performance under all reception conditions encountered on the survey.

8. DISCUSSION OF RESULTS

8.1 Static reception

The most important conclusion that can be drawn from the static part of the survey is that, over the nominal Band II service area, the reception of all types of RDS message can be expected to be extremely reliable using the receiving arrangements recommended for fixed installations. It is not anticipated that the reception of RDS will be significantly less reliable from the Radio 3 transmissions within their service area despite the relatively low injection level.

8.2 Mobile reception

All the tables show the expected strong correlation between the subjective quality grade of the received programme and the reliability of RDS reception. This indicates that the assessment of quality was consistent and gives confidence in the validity of the results.

As has already been pointed out, the survey was intended to be a comparative one and did not attempt to show the likely coverage of the RDS service directly. The results shown in the tables are primarily intended to indicate the likely performance of RDS as a function of the subjective quality of received sound programme. Using the tables it should be possible to predict the probable performance of RDS at any site or along any route, given a subjective assessment of the received sound programme quality.

The values of 'Total sent' associated with each subjective grade in the tables show the total numbers of each code transmitted during all the periods during which the received sound quality corresponded to that particular grade. These totals give an indication of the relative proportions of time during which each condition was encountered. Conclusions drawn on the basis of the above would be somewhat pessimistic because, as a result of experience during the early part of the survey, less attention was given to areas where reception was expected to be good.

8.3 The effect of the reduced subcarrier injection level on Radio 3

The tables show that RDS carried on Radio 3 performs worse than on Radio 2. However it is only for lower sound grades that the RDS performance becomes particularly poor on Radio 3, the nature of the programme material makes it unlikely that many listeners would want to listen to Radio 3 under these conditions.

8.4 The effect of low field strength

The results show that, if the received signal is both low in field strength and subject to multipath interference, then the RDS signal is received less reliably for a given sound quality grade than when the received signal is subject only to multipath interference.

This is not suprising, particularly in the case of PI code reception, because, in areas of high field strength, there will be frequent opportunities for the receiver to 'snatch' a PI code during peaks in the standing-wave pattern caused by the multipath interference. Where a combination of low signal strength and multipath interference produces the same subjective sound quality grade there will be a smaller proportion of time during which, for a comparable sound programme quality, the signal level is high enough to allow the reception of an RDS message.

The limiting case of this combination arises when there is no multipath interference and a low signal level. This was a condition not experienced during the survey with the vehicle on the move. In fact, in nearly all cases of low signal strength there was an indication of multipath interference. (There is a possibility that co-channel interference was also present in some cases; this would also have the effect of causing fluctuations in the reception of the RDS signal.)

As an indication, however, it is estimated that, under conditions of low signal strength but with no multipath interference, PI codes on Radio 3 should be received with a delay of, say, no more than one second when the received sound programme is as bad as Grade 2 (Poor).

8.5 The effect of message type

In accordance with expectation the PI codes (repeated eleven times per second) proved to be much more robust than the longer PS codes (repeated once per second).

For Radio 3 (C203) more than 90% of PI codes were received with no delay for received programme quality Grade 3 (Fair). In the case of Radio 2 (C202) this performance extended to Grade 2 (Poor) reception quality. With the exception of a very few entries in the 'bin' (see Section 5) the waiting time for successful reception of a code was not longer than one second for Radio 2 or Radio 3 for sound quality Grade 2 or better.

In the case of PS codes the performance is definitely inferior. Only about 65% of PS codes were received first time for sound quality Grade 3 (Fair). There were many more entries in the 'bin' for PS codes and many occasions when it would be necessary to wait for up to ten seconds for a successful reception.

A certain amount may be inferred about the probable reliability of reception of other messages such as Radiotext from the reception statistics of PS codes. Table 7 shows that, for Grade 3 (Fair) reception, nearly 35% of codes are either lost or their reception is delayed. This suggests strongly that Radiotext is unlikely to be reliably received in moving vehicles. There would be many instances, however, when a partly corrupted Radiotext message would be perfectly legible, if the context of the message were known.

9. CONCLUSIONS

A survey of the coverage of RDS has been carried out in the Wrotham Band II transmitter service area. The survey has shown that, at fixed installations with an elevated receiving aerial, extremely reliable reception of all types of RDS messages can be expected throughout the nominal service area.

Under mobile receiving conditions PI codes were received very reliably when the received sound quality was good. When impairments due to low field strength or multipath interference, or combinations of the two, reduced the received sound quality to Grade 2 (Poor) the PI codes were still successfully received at what was judged to be a sufficiently high rate to enable automatic tuning functions to be achieved. When sound reception was poor (to the extent that drivers would be unlikely to continue listening) only a very few instances were found where the successful reception of PI codes stopped for more than a few seconds.

The reception of PS codes was less reliable than reception of the PI codes under the same conditions. A simple receiver which displayed only the received PS codes for programme service identification might be expected occasionally to wait for a few seconds before revealing the PS name. Under many circumstances however, an intelligent receiver could use the more reliable PI codes to infer the same information.

The reduced level of injection of the experimental RDS signals on Radio 3 was found to reduce the reliability of data reception. However, the effect was only relevant for poor reception quality when, in any case, there would be less incentive for listening to critical programme material. Although RDS reception reliability was adequate with 1 kHz deviation, it was found that the higher deviation of 2.25 kHz gave significant improvement in reception reliability. It is therefore recommended that the higher deviation is used whenever possible.

10. REFERENCES

1. SHUTE, S. 1987. RDS: The EBU Radio Data System and its Implementation by BBC Radio. International Broadcast Engineer, Vol.18 No. 216, May 1987 and No. 217, July 1987.

2. EBU. 1984. Specifications of the Radio Data System RDS for VHF/FM Sound Broadcasting. EBU document Tech 3244-E.

3. ODMALM, C. 1983. The Development of the EBU VHF/FM Radio-data System (RDS), EBU Review (Technical) No. 200, August 1983.

4. MIELKE, J. and SCHWAIGER, K.H. 1986. Progress with the RDS System and Experimental Results. EBU Review (Technical) No.217, June 1986.

Table 2

Radio 2 (PI code C202 — 2.25 kHz injection level): All reception conditions

Delay (d) (Number of codes lost before success)	PI codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 0)	Grade 2 (Total sent = 2665)	Grade 3 (Total sent = 47993)	Grade 4 (Total sent = 33572)	Grade 5 (Total sent = 21194)
0		9118	9306	9876	9988
1		221	220	26	5
2		63	30		
3		15	9		
4		11	4		
5		11	1		
6		3			
7					
8					
9		3			
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
‘BIN’					
10 S			3		
30 S			1	1	
1 M					
5 M					
20 M					

Table 3

Radio 2 (PI code C202 — 2.25 kHz injection level): Medium/high field strength

Delay (d) (Number of codes lost before success)	PI codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 0)	Grade 2 (Total sent = 2665)	Grade 3 (Total sent = 46762)	Grade 4 (Total sent = 33572)	Grade 5 (Total sent = 21194)
0		9118	9282	9876	9988
1		221	215	26	5
2		63	28		
3		15	8		
4		11	4		
5		11	1		
6		3			
7					
8					
9		3			
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
‘BIN’					
10 S			3		
30 S			1	1	
1 M					
5 M					
20 M					

Table 4

Radio 3 (PI code C203 — 1 kHz injection level): All reception conditions

Delay (d) (Number of codes lost before success)	PI codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 11975)	Grade 2 (Total sent = 89128)	Grade 3 (Total sent = 76205)	Grade 4 (Total sent = 13914)	Grade 5 (Total sent = 1030)
0	6202	8521	9202	9492	10000
1	577	375	258	125	
2	173	79	33	12	
3	3	28	8	2	
4	40	10	2		
5	29	6	2		
6	12	4			
7	11	2			
8	5				
9		1			
10	1				
11	3				
12	1				
13	1				
14	1				
15	1				
16					
17	2				
18					
19					
20					
21					
22					
‘BIN’					
10 S	2	18	13		
30 S	4			1	
1 M		1			
5 M					
20 M					

Table 5

Radio 3 (PI code C203 — 1 kHz injection level): Medium/high field strength

Delay (d) (Number of codes lost before success)	PI codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 11975)	Grade 2 (Total sent = 89128)	Grade 3 (Total sent = 76205)	Grade 4 (Total sent = 11528)	Grade 5 (Total sent = 1030)
0	6202	8521	9202	9423	10000
1	577	375	258	134	
2	173	79	33	14	
3	3	28	8	2	
4	40	10	2		
5	29	6	2		
6	12	4			
7	11	2			
8	5				
9		1			
10	1				
11	3				
12	1				
13	1				
14	1				
15	1				
16					
17	2				
18					
19					
20					
21					
22					
'BIN'					
10 S	2	18	13		
30 S	4			1	
1 M		1			
5 M					
20 M					

Table 6

Radio 2 (PS code BBC R2 — 2.25 kHz injection level): All reception conditions

Delay (d) (Number of codes lost before success)	PS codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 870)	Grade 2 (Total sent = 4135)	Grade 3 (Total sent = 6201)	Grade 4 (Total sent = 2450)	Grade 5 (Total sent = 0)
0	2609	5721	6969	8734	
1	413	986	1301	542	
2	160	188	151	32	
3	103	60	29	8	
4	34	45	20		
5	11	9	4	8	
6		29	6		
7	34	12	3		
8		9	1		
9		2			
10	11	2	1		
11					
12			1		
13		4			
14					
15	11		1		
16					
17					
18		2			
19		4			
20					
21	11				
22					
'BIN'					
1 M	1	2	1		
5 M	4	2			
20 M					

Table 7

Radio 2 (PS code BBC R2 — 2.25 kHz injection level): Medium/high field strength

Delay (d) (Number of codes lost before success)	PS codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 0)	Grade 2 (Total sent = 3502)	Grade 3 (Total sent = 4239)	Grade 4 (Total sent = 2535)	Grade 5 (Total sent = 0)
0		6373	6518	8777	
1		1122	1165	524	
2		214	250	31	
3		54	23		
4		31	18		
5		2	2	7	
6		17	4		
7		5	2		
8		5	2		
9		2			
10					
11					
12			2		
13		2			
14					
15			2		
16					
17					
18					
19					
20					
21					
22					
'BIN'					
1 M		2	1		
5 M					
20 M					

Table 8

Radio 3 (PS code BBC R3 — 1 kHz injection level): All reception conditions

Delay (d) (Number of codes lost before success)	PS codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 2760)	Grade 2 (Total sent = 7950)	Grade 3 (Total sent = 7113)	Grade 4 (Total sent = 343)*	Grade 5 (Total sent = 204)*
0	1206	3655	6613	9941*	10000*
1	239	493	982	29*	
2	126	174	208		
3	21	94	71		
4	32	46	35		
5	14	42	23		
6	21	15	12		
7	10	13			
8	7	18			
9		13	4		
10	18	5	2		
11	3	8			
12	7	10			
13	7	6			
14		11			
15		1	1		
16	7	1			
17		1			
18		5			
19	10	2			
20	3	1			
21	3	3			
22					
'BIN'					
1 M	12	17			
5 M	9	11			
20 M					

* Small sample

Table 9

Radio 3 (PS code BBC R3 — 1 kHz injection level): Medium/high field strength

Delay (d) (Number of codes lost before success)	PS codes received after delay d (per 10,000 sent)				
	Grade 1 (Total sent = 969)	Grade 2 (Total sent = 6960)	Grade 3 (Total sent = 5293)	Grade 4 (Total sent = 343)*	Grade 5 (Total sent = 204)*
0	650	4109	6803	9941*	10000*
1	165	596	1037	29*	
2	30	222	181		
3	41	103	66		
4	30	47	24		
5	20	53	7		
6	20	17	9		
7		11			
8	10	17			
9		14	1		
10		5	1		
11		5			
12	10	10			
13	10	10			
14		11			
15		1	1		
16		1			
17					
18		2			
19		5			
20	10	1			
21	3	4			
22					
'BIN'					
1 M	4	15			
5 M	4	5			
20 M					

* Small sample

APPENDIX 1

Summary of the RDS Specification

A1.1 Modulation characteristics

The RDS data signal has a bit rate of 1187.5 bit/s and is bi-phase coded and shaped, with a 100% cosine roll-off frequency characteristic. The data signal is also differentially coded to resolve phase ambiguity. This signal is applied to a 57 kHz subcarrier using double-sideband suppressed carrier modulation (bi-phase modulation*) by the (NRZ) data signal.

The above parameters allow the maximum subcarrier injection level for the required data rate, consistent with compatibility with the sound programme signal.

A1.2 The baseband coding

The data is baseband coded into groups of 104 bits. Each of these groups comprises four blocks, each of which consists of 16 data bits and a checkword of 10 bits. The checkword provides error protection[1]. The error protecting system may be used to correct short bursts of errors or to detect longer bursts. The choice of correction or detection is a receiver manufacturer's option and the best choice will depend on the nature of the message being received. (See Section 5.2)

A1.3 RDS codes and message types

There is a wide variety of code types which may be sent[1] and a range of repetition rates, depending on the kind of message and the reliability of reception required. Table 1 contains a list of the code types which may be transmitted.

Short, rapidly repeated messages, are sent in 'machine code' form. For instance, the PI (Programme Identification) codes consist of four hexadecimal characters which identify the country of origin, type of coverage (e.g. national, international, regional, etc.) and programme reference number. Thus C202 (hexadecimal) is the PI code carried by BBC Radio 2 transmissions and C203 (hexadecimal) is carried by BBC Radio 3 transmissions nationally. PI codes are transmitted a minimum of eleven times per second. This high repetition rate is necessary to enable, for instance, automatic tuning by intelligent receivers. Other codes which require high repetition rates are TP (Traffic Programme Identification) and PTY (Programme Type).

Other codes are not repeated as rapidly. These may either be short, such as TA (Traffic Announcement Code), which comprises one data bit, repeated four times per second, or relatively long, such as PS (Programme Service) which consists of a string of up to eight ASCII characters, repeated four times per second. RT (Radiotext) codes may be used to transmit ASCII strings of up to 64 characters and may be repeated once every 5 seconds.

APPENDIX 2

The Data-logging Program and Analysis of Error Performance

The main part of the computer program was written, for convenience, in BBC BASIC. However, BBC BASIC was not fast enough to assimilate the reception statistics in real time and so parts of the program were written in 6502 assembly language. A 'background' program was written in BBC BASIC which updated the display with the reception statistics. An interrupt routine which logged the arrival of the wanted RDS codes was called by the internal timer in the microcomputer at regular intervals. This routine was written in 6502 assembly language, which operates about a thousand times faster than BBC BASIC. The routine 'looked for' the wanted codes in the RS423 input buffer at times when it might expect to find a newly-received code. If the code was not received, the program incremented the total of missed codes. When, eventually, a correct code was received the interrupt routine incremented the appropriate histogram total (see Fig. 6) and started looking for a code again.

---

* The carrier phase is switched between two values, separated by pi radians.

The following may help to explain the significance of the histogram form of representation. If w is the number of lost messages between two successfully received messages and N(w) is the number of occasions on which w messages were lost then T, the total number of messages transmitted in any analysis period, will be given by:-

$$T = \sum N(w).(w+1)$$

A 'listing' of the software is not included here but the next two sub-sections contain descriptions of the main features of the error analysis program. The descriptions of the main program and the interrupt routine are written in a form of 'computerese' which, it is hoped, will help in the understanding of the procedure.

A2.1 Summary of analysis program (main program)

```
BEGIN
Configure the parallel I/O port to accept clock and data from the RDS decoder. Set up the RS423 serial port to receive the ASCII output from the RDS decoder. Assemble the interrupt and initialisation routines. Ask for the output file name. Open an output file. Ask for the expected RDS code. (Four ASCII (hex) characters for PI codes or eight alphanumeric characters for PS codes).
REPEAT
        Examine the RS423 input buffer.
UNTIL the required RDS code is input from the RDS decoder.

Initialise the BBC Microcomputer internal timer to produce interrupt pulses at the same rate as RDS codes are transmitted. 'Patch' the user interrupt routine into the system interrupt vector. Set all histogram totals to zero.
REPEAT
        Enable User Interrupt
        REPEAT
                Look at all the totals (all N(w) values).
                Re-write the histogram on the screen. (See Figure 6).
        UNTIL end of measurement period
                Disable user interrupt.
                Ask for subjective grade and other comments.
                Dump all screen data plus comments onto file.
                Reset all histogram totals to zero.
UNTIL end of run.
Close file.
END
```

A2.2 Summary of user interrupt routine.

```
BEGIN
'Push' all registers.
IF RS423 buffer contains wanted RDS character string.
   THEN examine total number of codes lost since last successful reception.
   IF number of lost codes is greater than 22 (i.e. more than 2 seconds delay for PI codes or 5.5 seconds for PS codes)
           THEN increase appropriate 'bin' total.
           ELSE increment appropriate histogram column.
           END IF
   ELSE increment total number of codes lost since last successful reception.
   END IF
'Pop' all registers.
RETURN
```